Using the Singular Spectral Analysis method to analyze VLBI time series

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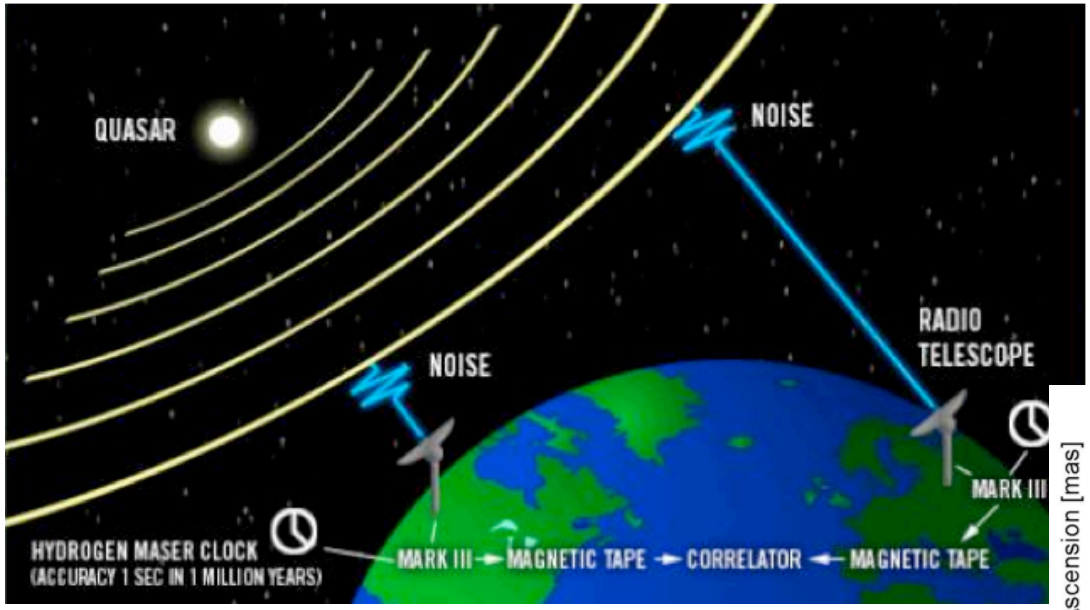
Contents

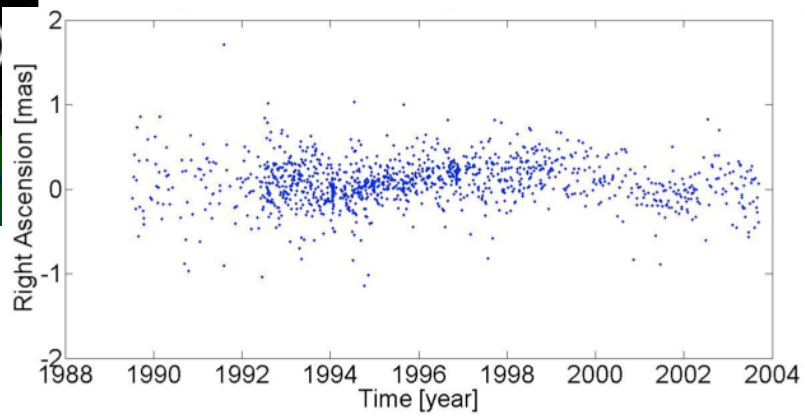
- ***Context: Time series in VLBI;***
- ***Tools used: SSA and Allan variance;***
- ***Using the SSA to analyze UT1-TAI;***
- ***Predicting VLBI source position (1308+326);***
- ***Conclusions and perspectives.***

VLBI and its time series



Source 1308+326

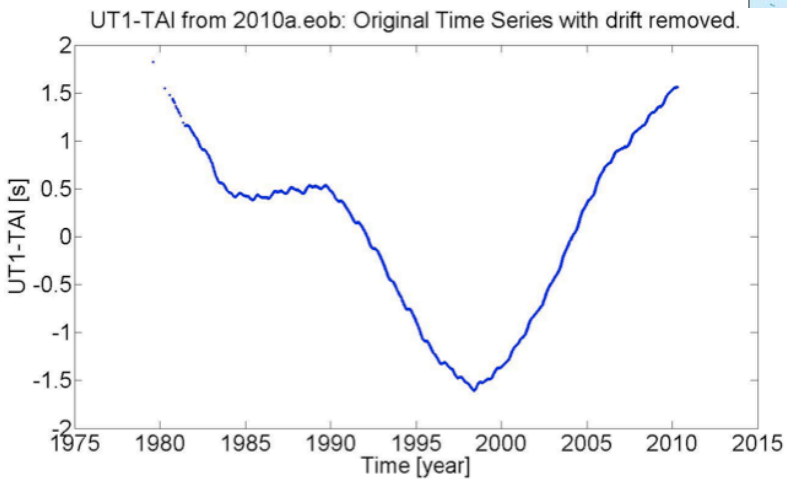
Right ascension x cos (declination)

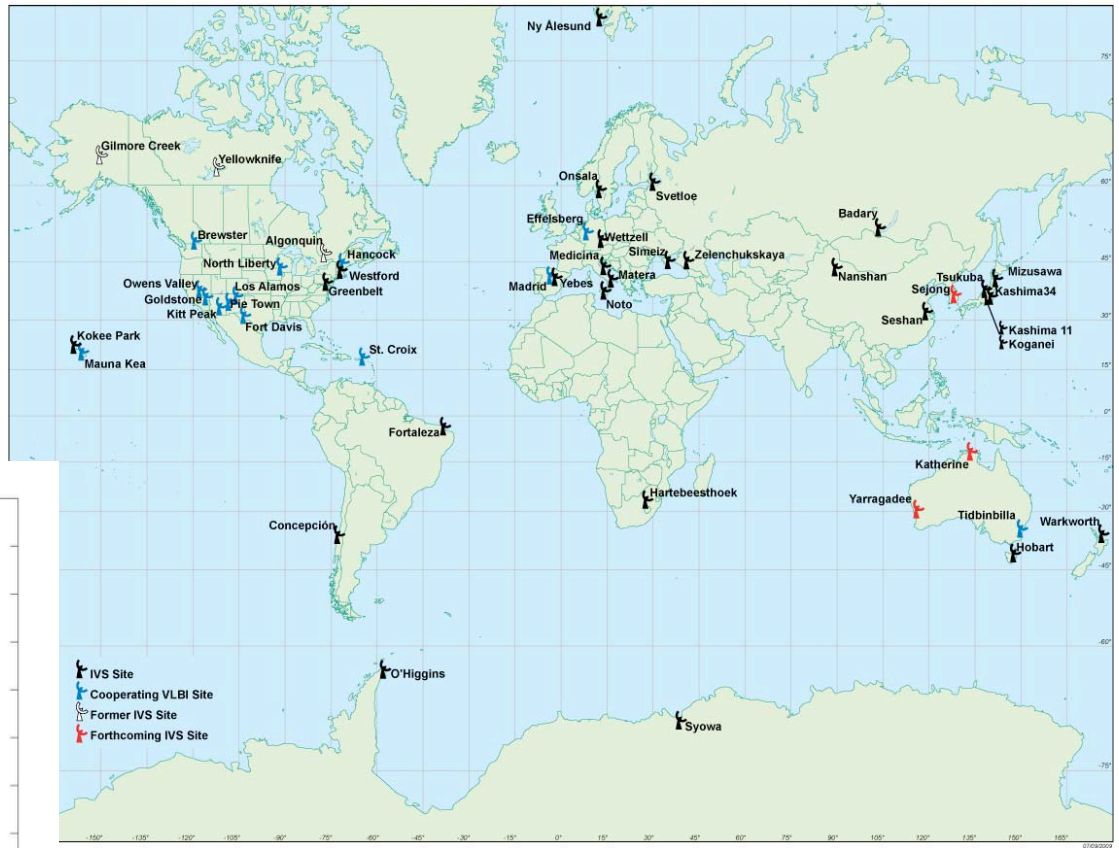


- Observations:
  - Sources (right ascension, declination);
  - Meteorologic data (P,T,H);
  - Stations.
- Sources and stations are not observed regularly (availability of the stations in the scheduling, station's breakdown,…).

VLBI and its time series

- Data processing:
  - Earth Orientation Parameters;
  - Celestial Reference Frame (sources);
  - Terrestrial Reference Frame (stations);
  - Tropospheric parameters.

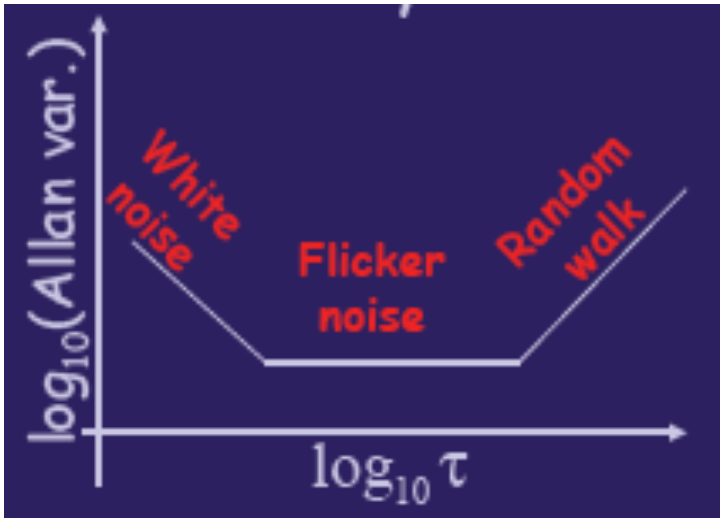




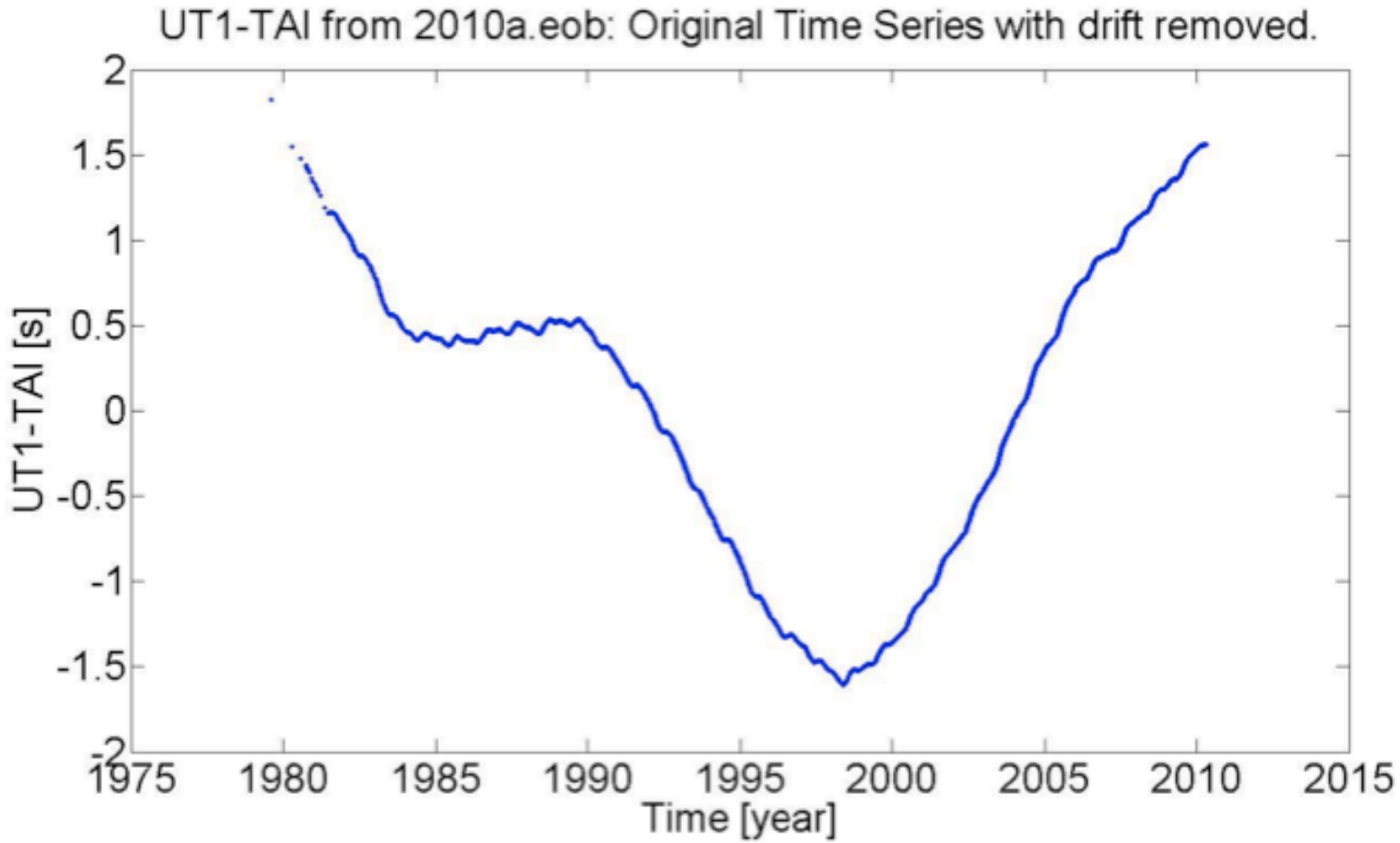
Statistical tools used to analyze time series

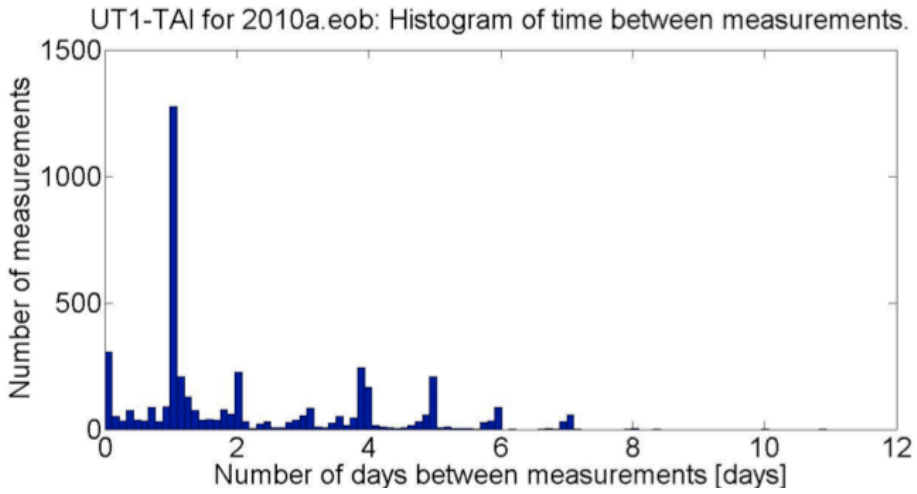
- The Singular Spectral Analysis (SSA):
  - To extract the main signal;
  - To regularize;
  - To predict.
- Type and level of noise:

  Allan variance.



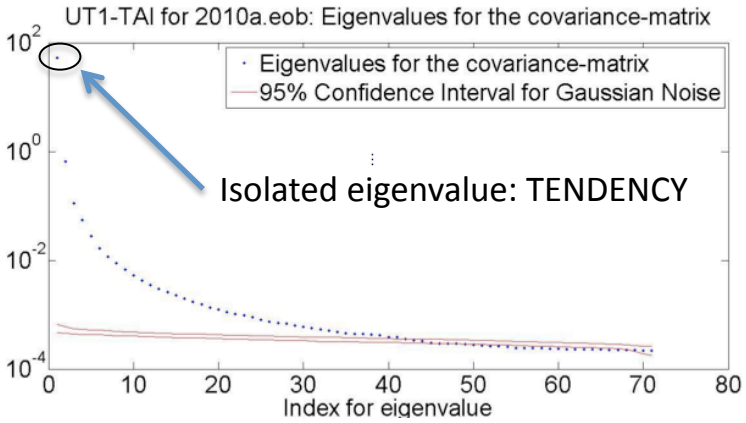
UT1-TAI analysis



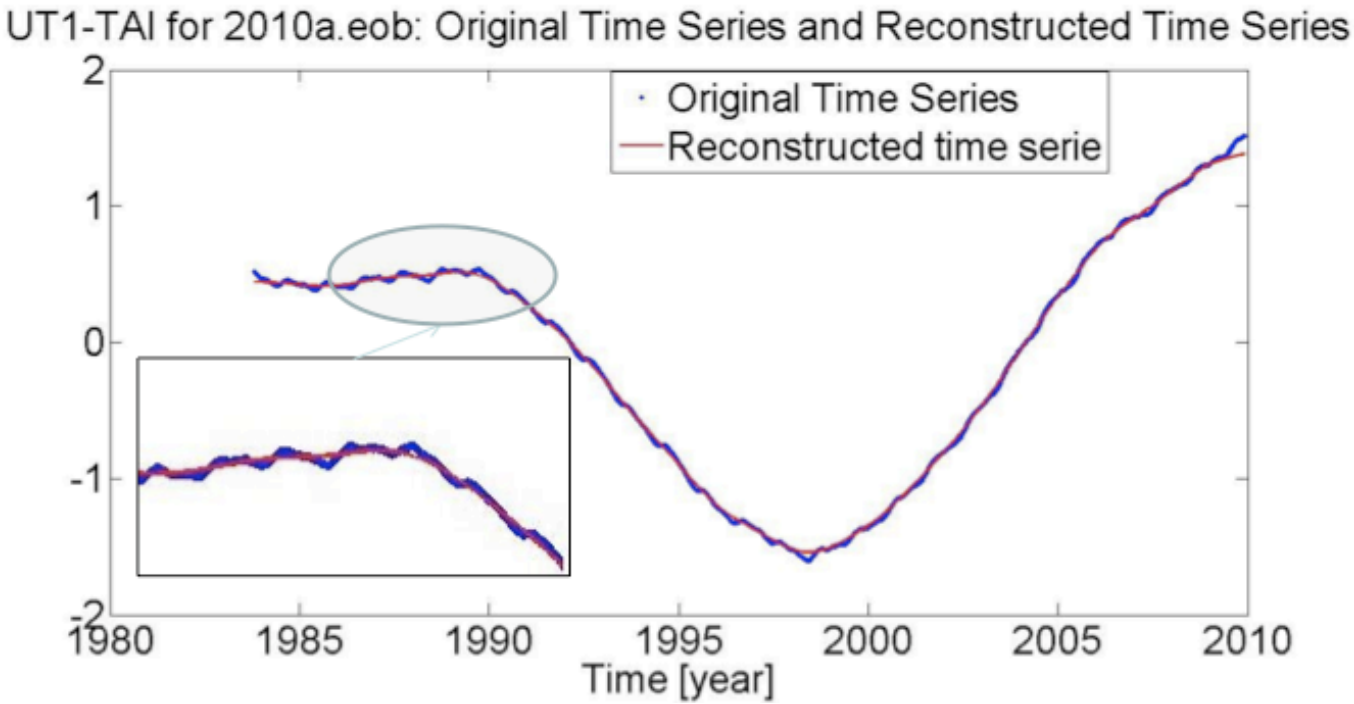


UT1-TAI analysis: Regularization of the data span

- Common difficulty in VLBI time series analysis:
  - The time span between measurements is irregular.
- Solution adopted: discretization
  - Choice of an appropriate gridspace to define an equispaced time grid;
  - Weighted average of data to transform the original time series to the equispaced time grid;
  - Filling the gaps by iteratively solving the SSA (Zhang's iterative SSA approach / Section 9.2 of Elsner/Tsonis textbook).

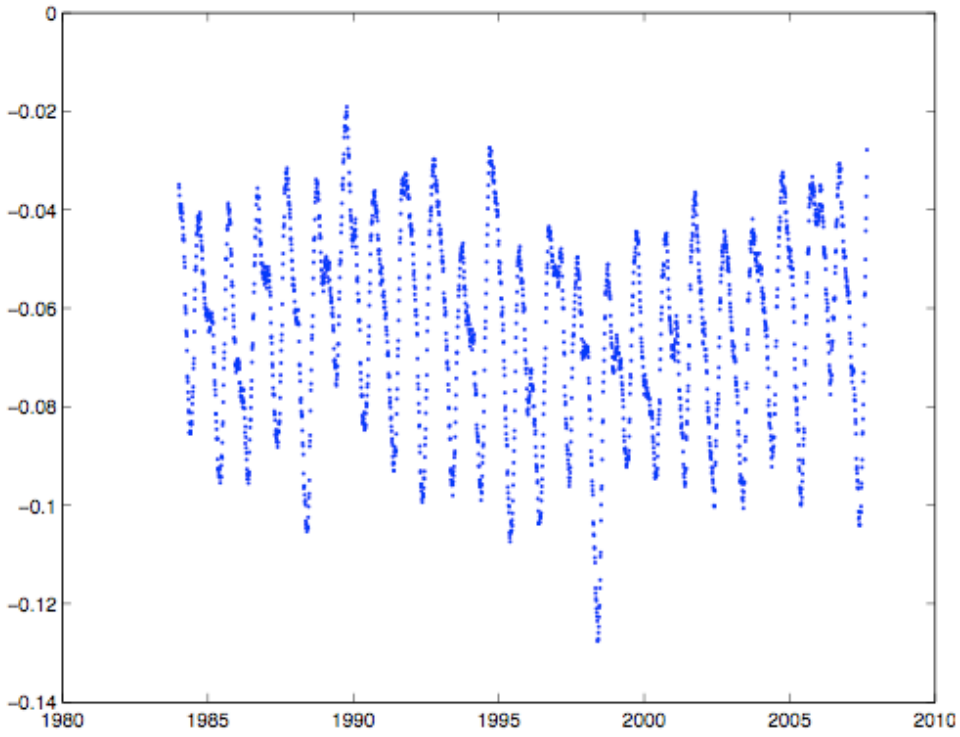


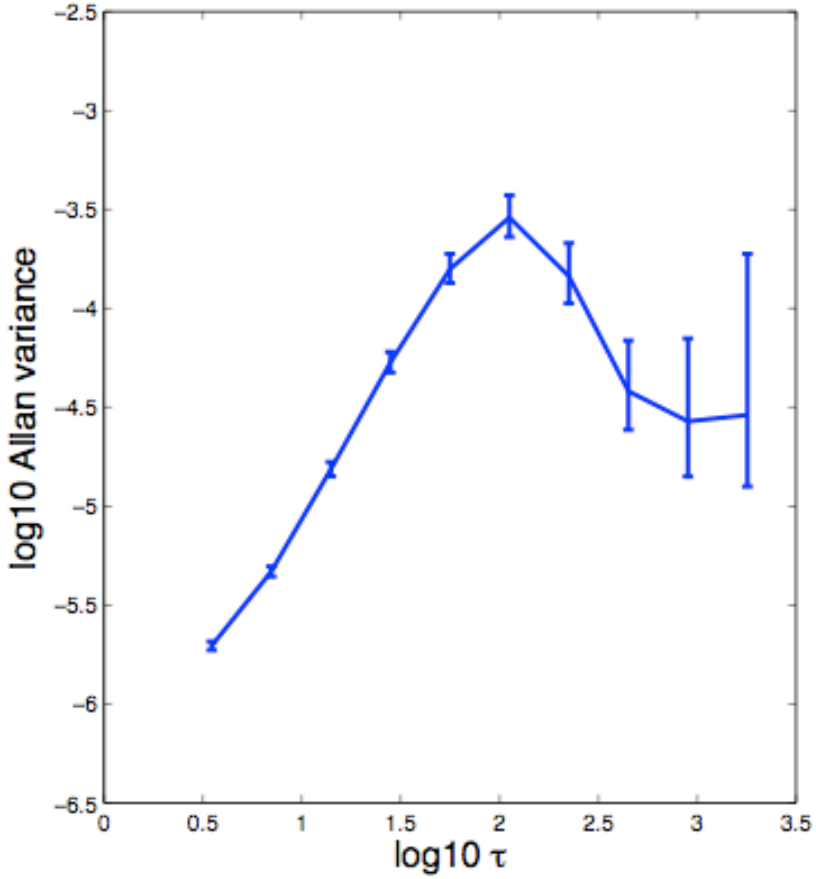
UT1-TAI analysis: SSA First iteration



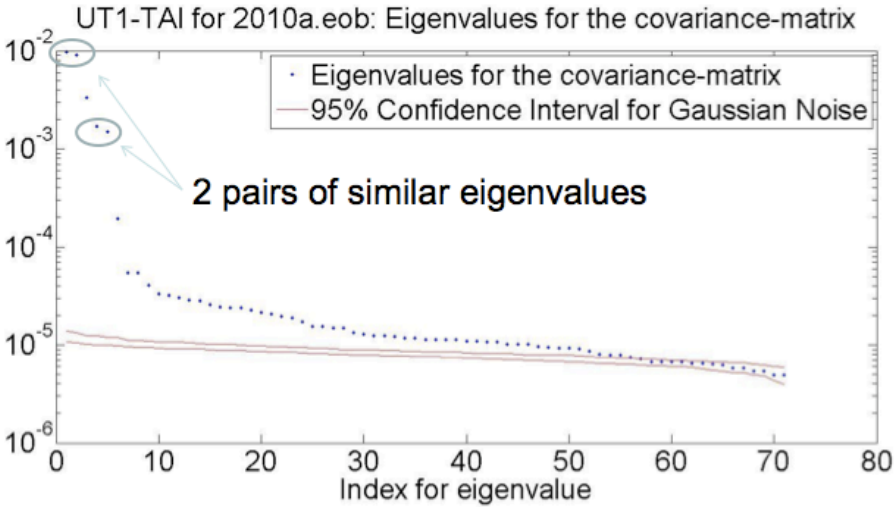
UT1-TAI analysis: SSA First iteration

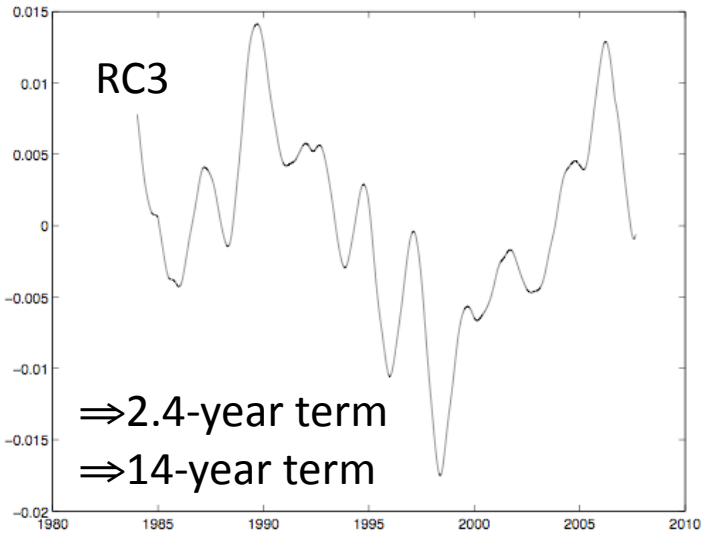
Residual time series and Allan variance

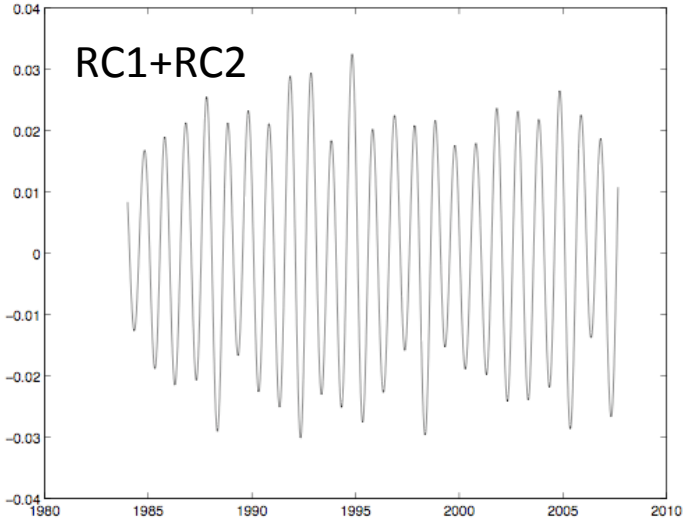


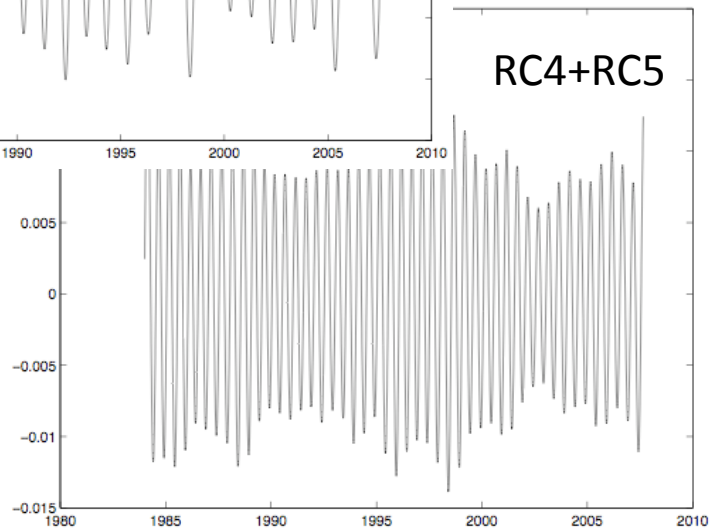


UT1-TAI analysis: SSA Second iteration



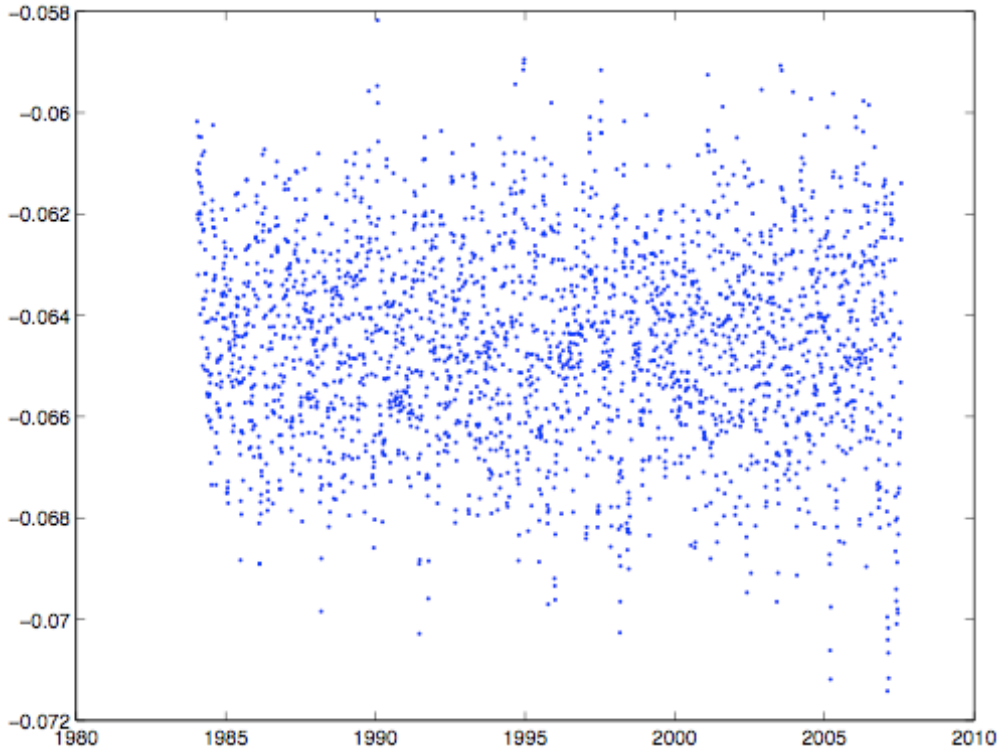


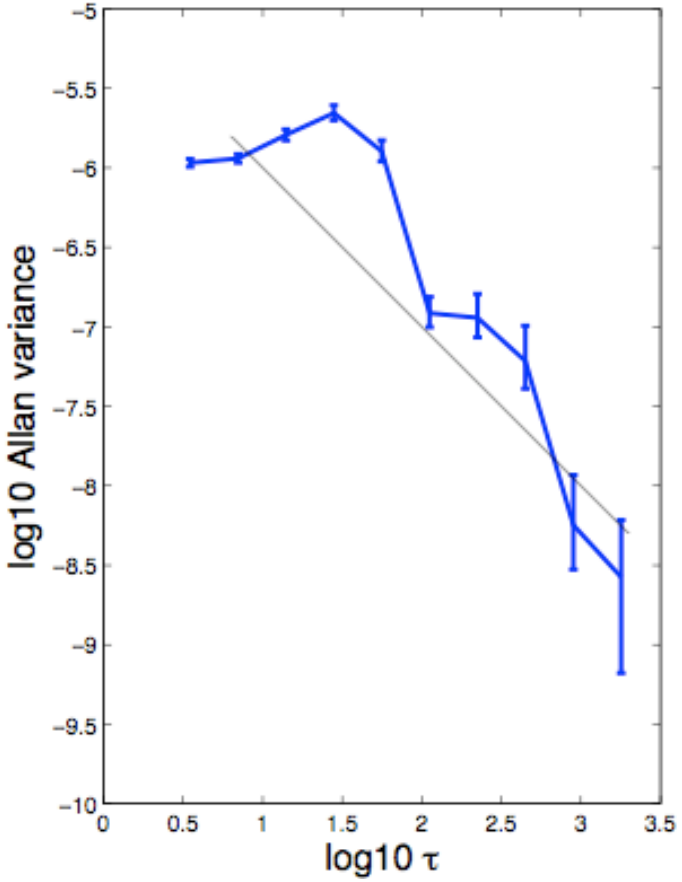




UT1-TAI analysis: SSA Second iteration

Residual time series and Allan variance

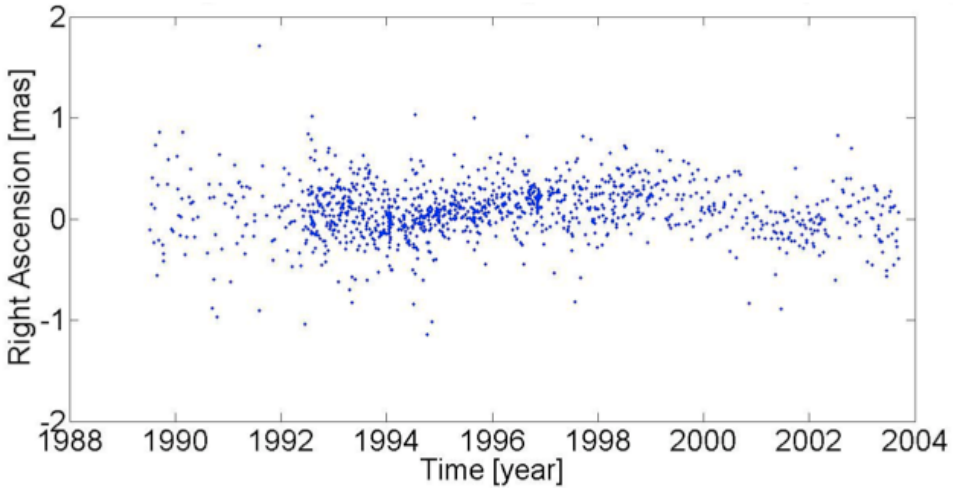




UT1-TAI – Conclusions

SSA decomposes the time series:

- Tendency
- Periodic signals:
  - annual, semi-annual, 14-year, 2.4-year
- White noise.

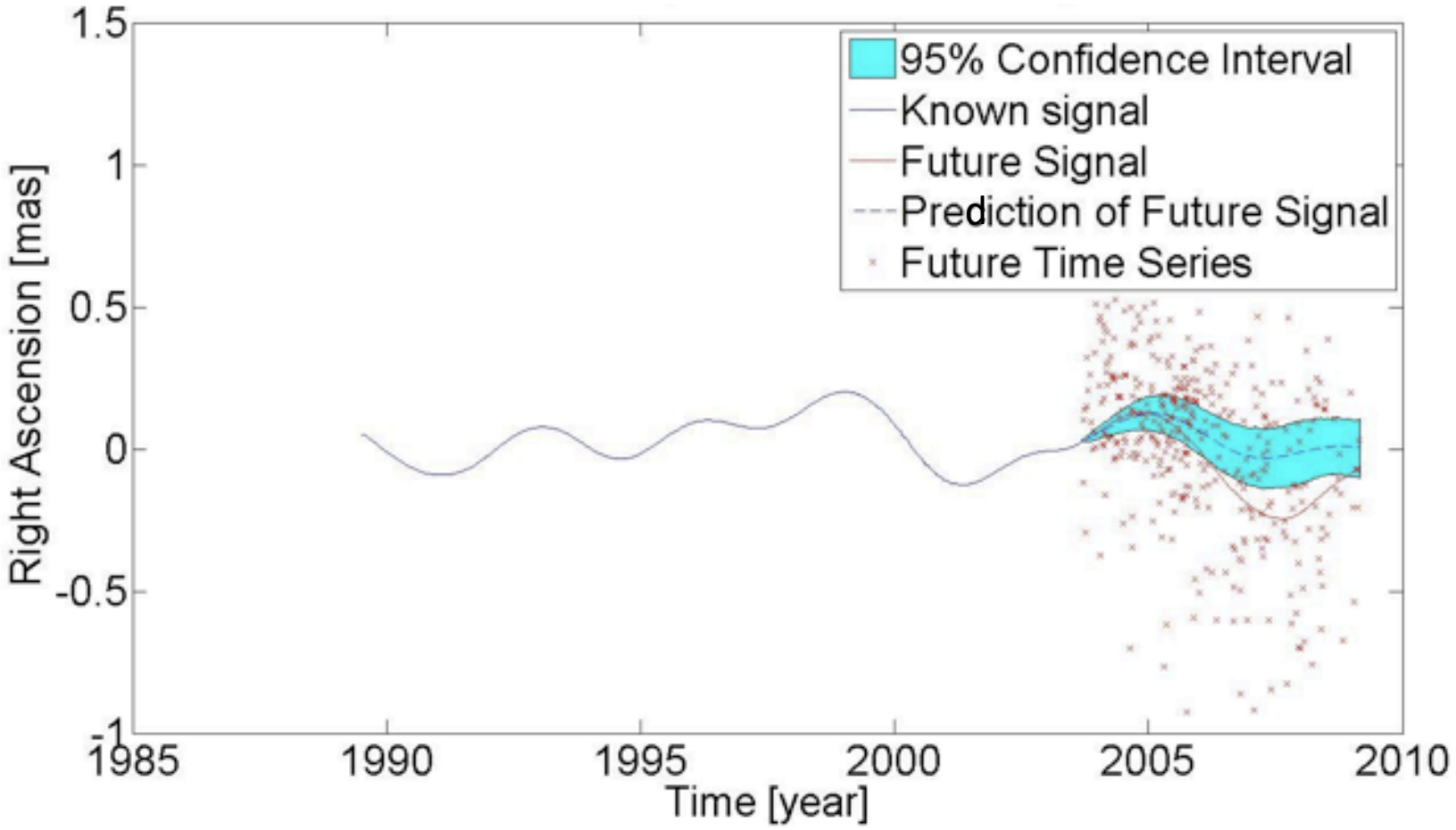


Source 1308+326 Prediction of signal

- Possible reasons for scatter: source structure, hardware/software, geometry of the observation (schedules),…
- Reconstructed Components *RC* (from SSA analysis) are modeled as an Auto Regressive process of order n: $X_t = \sum_{i=1}^{n} \varphi_i X_{t-i} + \varepsilon_t$

  where φ_i are the parameters of the process and ε_t is white noise.
- Prediction by:
  - Calculating the parameters from known data;
  - Simulating surrogate data for each RC and sum the components.

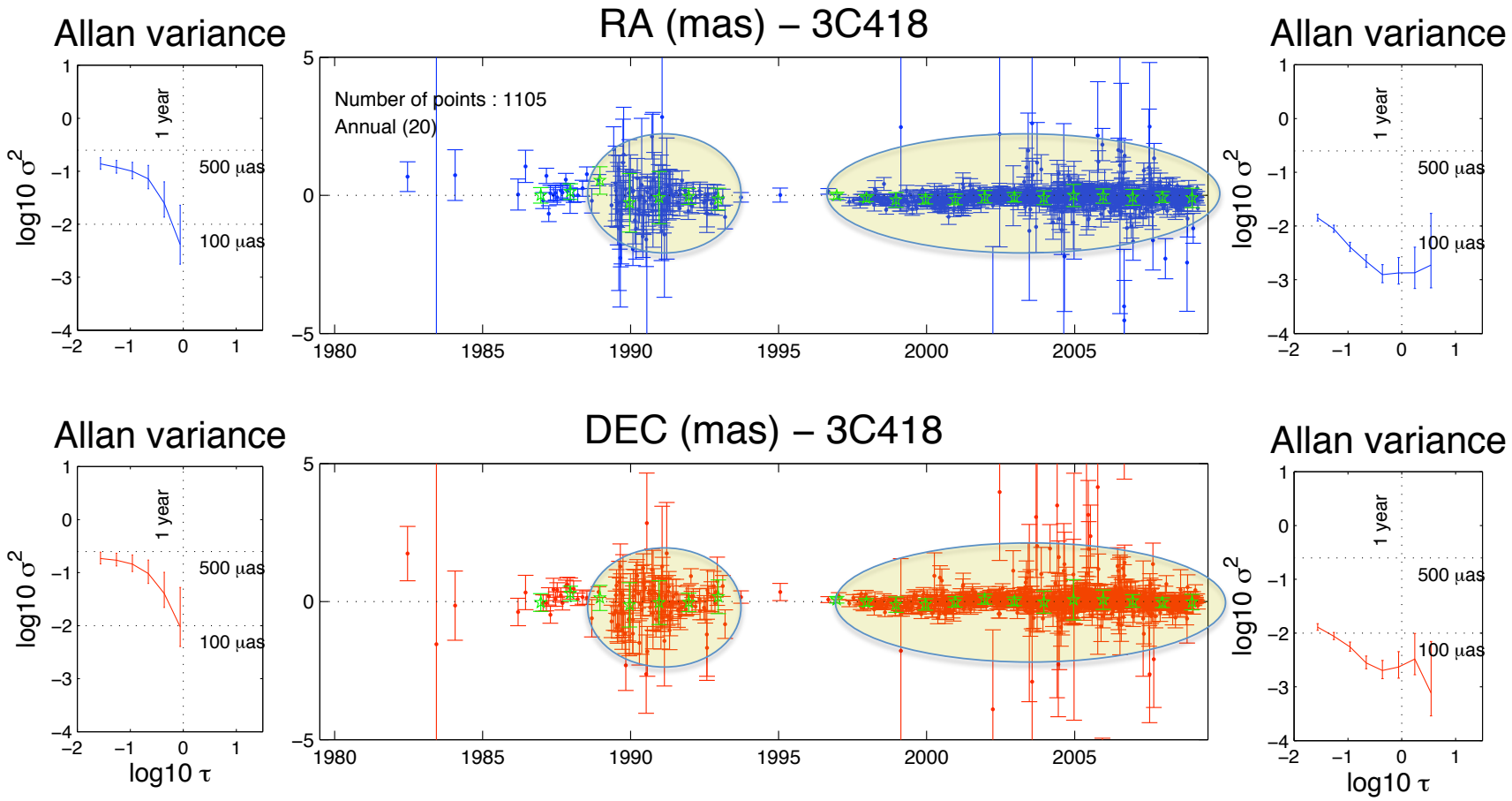
Source 1308+326 - Prediction of signal



Conclusions and perspectives

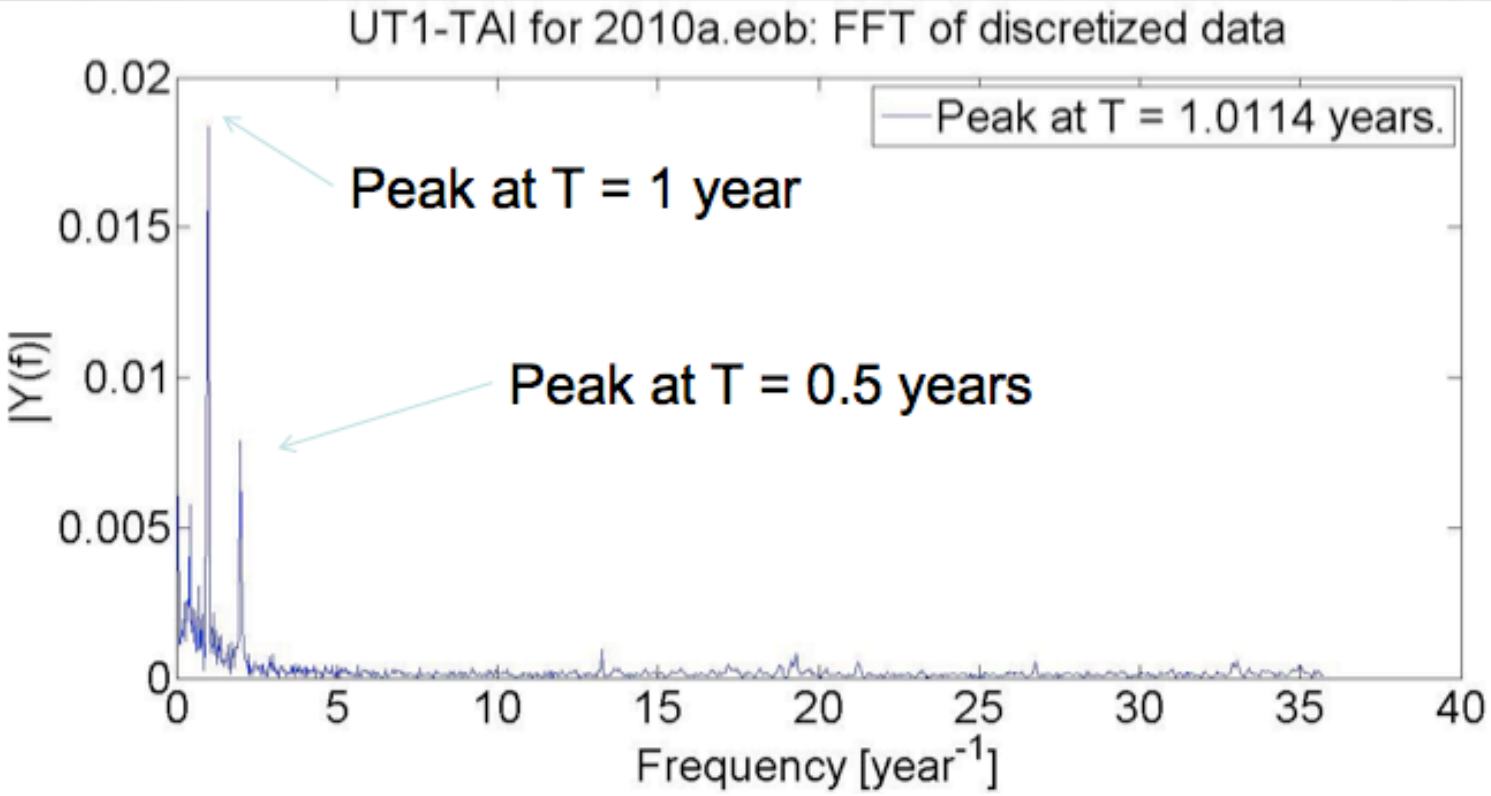
- Conclusions:
  - The signal in UT1-TAI time series is complex and composed of periodic signals of different periods and white noise.
  - The SSA may be used to predict source position changes in time and is efficient in the short-term (one to two years).
- Perspectives:
  - Testing the impact of the discretization step on the time series.
  - Repeating the analysis on other VLBI time series (global station network).
  - MSSA applied to multi-variate VLBI time series and comparison with PCA.

Discussion: stationarity

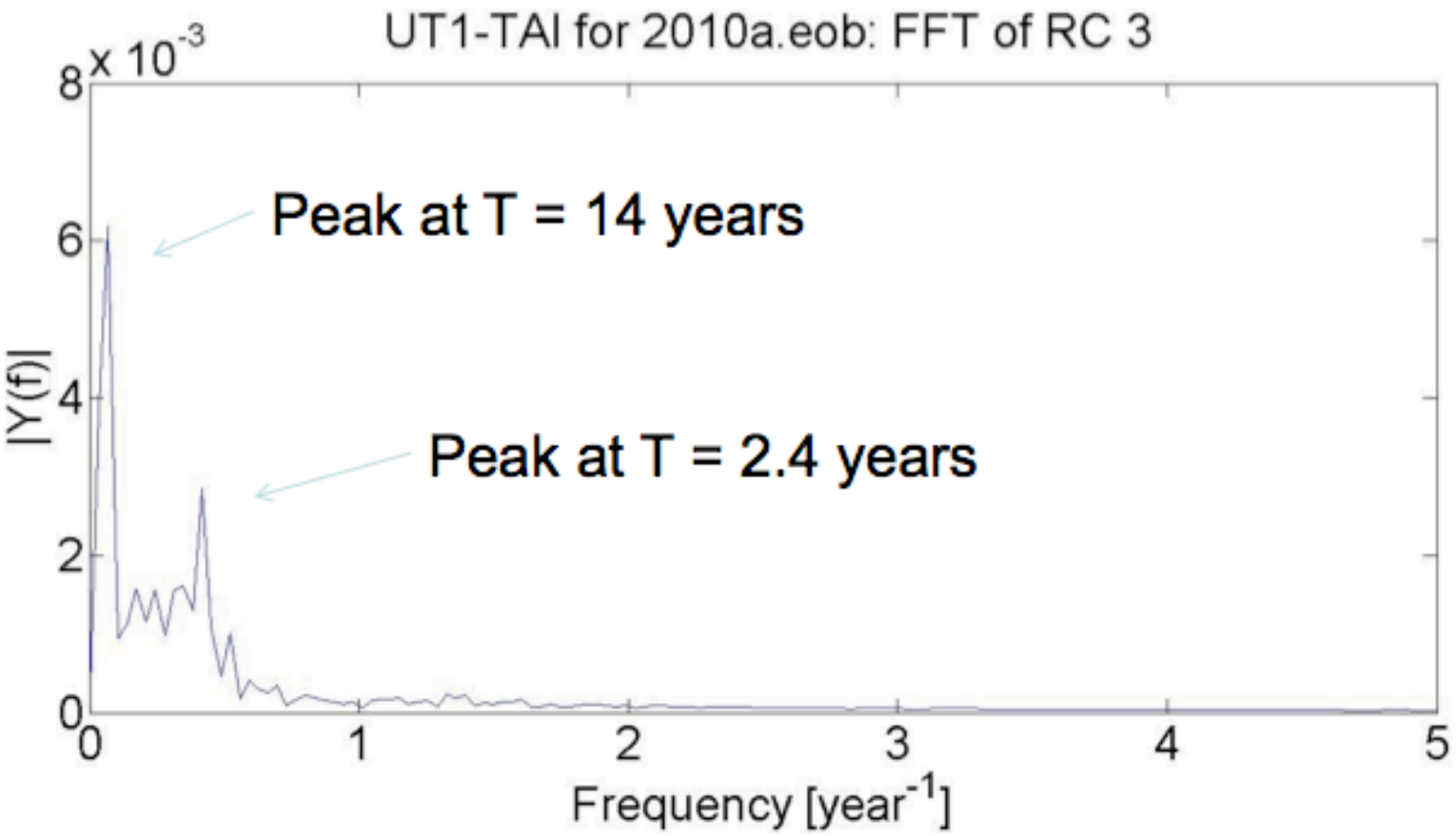


UT1-TAI (SSA)

- PSD after removing low-frequency component:



UT1-TAI (SSA)


UT1-TAI for 2010a.eob: FFT of RC 3
x 10^-3
8
6
4
2
0
|Y(f)|
Peak at T = 14 years
Peak at T = 2.4 years
0
1
2
3
4
5
Frequency [year^-1]

El Niño / La Niña

- El Niño refers to the large-scale ocean-atmosphere climate phenomenon linked to a periodic warming in sea-surface temperatures across the central and east-central equatorial Pacific;

- La Niña refers to the periodic cooling of ocean surface temperatures in the central and east-central equatorial Pacific.

- El Niño:
  - 1986/08-1988/02
  - 1991/05-1992/07
  - 1994/05-1995/03
  - 1997/04-1998/05
  - 2002/05-2003/03
  - 2004/05-2005/02
  - 2009/06-2010/04
- La Niña:
  - 1984/10-1985/09
  - 1988/05-1989/05
  - 1995/09-1996/03
  - 1998/07-2000/06
  - 2000/09-2001/02
  - 2007/04-2008/05